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B.C. HYDRO AND POWER AUTHORITY

Report on

1982 GEOLOGICAL MAPPING PROGRAM, NORTH RESERVOIR AREA, MEAGER CREEK, B.C.

by

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GEOLOGISTS AND ENGINEERS

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1.0 INTRODUCTION

1.1 Terms of Reference

Reconnaissance exploration in the North Reservoir area began in 1978 (NSBG, 1979) in order to evaluate its geothermal potential. This potential is indicated by the Pebble Creek Hot Springs, an H_2S gas vent, and the youngest eruptive centres of the Meager Volcanic Complex, all of which lie in close proximity to one another. The exploration program for 1982 was aimed at identifying deep exploratory drill targets and included hydrogeochemical and geophysical surveys, temperature gradient drilling, and geologic mapping.

This report presents the results of geological mapping carried out in the North Reservoir area (Figure 1). The objectives of the mapping program were:

(1) to identify major structural features;
(2) to map and sample alteration zones;
(3) to relate alteration to structural features; and
(4) to provide geologic information necessary in evaluating geophysical, hydrogeochemical, and drill-hole data.

1.2 Location and Access

The study area is located on the north side of the Meager Volcanic Complex which lies about 160km north-northwest of Vancouver and 60km northwest of Pemberton, B.C. (Figure 1). The area is bounded on the west by Mosaic Creek, on the east by Crazy Creek and Plinth Mountain, on the south by Job, Affliction and Mosaic Glaciers, and on the north by the Lillooet River. Access to the northeast corner of the study area is by logging road from Pemberton. The rest of the area can be reached only by foot or helicopter.

Bedrock is exposed mainly on the steep, unstable walls of glacially-scoured valleys or around alpine meadows. Most ridge crests and mountain tops are capped by rocks of the Meager Volcanic Complex.

1.3 Previous Studies

Regional mapping of the entire Meager Volcanic Complex was done by Read (1979). Reconnaissance mapping of pre-volcanic (basement) rocks in the North Reservoir area has been carried out since 1979 by NSBG as an adjunct to geophysical surveys and drilling operations. In 1981 B.C. Hydro carried out geologic and structural studies in

Affliction Creek valley and Fall Creek drainage (McCullough, 1982).

1.4 Present Work

The 1982 mapping program was designed to complement and extend studies so far conducted and to test hypotheses generated from them. Field work was accomplished in two and a half weeks in August, 1982. It consisted of bedrock mapping in Job, Affliction, and Mosaic Creek valleys and their tributaries in order to establish stratigraphy and major structures. Attention was paid to geologic features, such as alteration zones, precipitates and minor structures, that could indicate current or recent hydrothermal activity. Petrographic and structural analyses followed field work. A preliminary map with marginal notes was submitted to BCHPA in September, 1982.

2.0 GEOLOGY

2.1 Introduction

The geology of the North Reservoir area can be divided into four main parts: (1) sequences of folded metamorphic rocks, that have been intruded by (2) several granitic to dioritic plutons ranging in age from Mesozoic to Tertiary. Together these form a "basement" which has been overlain and intruded by (3) Pliocene to Recent volcanic and associated hypabyssal rocks of the Meager Volcanic Complex. Unconsolidated surficial deposits (4), such as till, alluvium, and debris flows, mantle hill sides and valley bottoms.

The basement is part of the Coast Mountains plutonic complex, a series of granitic batholiths with metamorphic enclaves or septa, that trends northwesterly from Vancouver to Alaska. The metamorphic enclaves represent rocks from which the plutons were derived or into which they were intruded. This crystalline basement is the probable reservoir rock of any exploitable geothermal system to be found at Meager Creek.

In the map area (Figure 5), plutonic rocks have been divided into 5 units (Units 3,4,5,7 and 8) based on composition and relative age derived from crosscutting relationships, degree of recrystallization, and published radiometric ages (Read, 1979). Three different ages of metamorphic rocks have been identified in the vicinity of

TABLE 1: TABLE OF FORMATIONS

UNIT		
10	Quaternary surficial deposits: undifferentiated talus, alluvium, debris flows	
9	Pliocene to Recent volcanic rocks: includes flows, tephra, hypabyssal intrusions	
	9	Undifferentiated
	9a	Olivine-pyroxene-plagioclase-porphyry basalt (P10x,f)
	9b	Light to medium grey, plagioclase-biotite-quartz-porphyry rhyodacite (P9x,f,i)
	9c	Dark grey to purple, plagioclase-quartz-biotite-porphyry rhyodacite (P8x,f,i)
	9d	Rusty-yellow weathering, plagioclase-quartz-hornblende-biotite-porphyry rhyodacite (P7x,f)
	9e	Light grey, plagioclase-hornblende-porphyry andesite (P6x,f,i)
	9f	Plagioclase-pyroxene-porphyry andesite (P3x,f)
8	Tertiary (Miocene) intrusive rocks	
	8	Undifferentiated
	8a	Affliction Creek Stock (biotite granite, granodiorite)
	8b	Fall Creek Stock (leucogranite)
7	Cretaceous(?) intrusive rocks: late- to post-tectonic granitoid sills; age relative to Unit 6 not known	
	7	Undifferentiated
	7a	Biotite tonalite
	7b	Hornblende-biotite quartz diorite
	7c	Hornblende-diorite, metadiorite; biotite-hornblende diorite; hornblende-megacrystic diorite
6	Lower Cretaceous(?) Gambier(?) Group: volcanic and sedimentary rocks (not exposed in area mapped)	
5	Cretaceous(?) dykes: altered and recrystallized hypabyssal dykes found cutting Units 2, 3, and 4	
	5	Undifferentiated
	5a	Medium grey, fine grained, plagioclase-porphyry, altered diorite
	5b	Medium green, very fine grained, meta-andesite
4	Jurassic(?) to Cretaceous(?) intrusive rocks: pre- to syn-tectonic; mainly hornblende-biotite quartz diorite	
	4	Undifferentiated
	4a	Random textured, hornblende-biotite quartz diorite
	4b	Variably foliated, hornblende-biotite quartz diorite
	4c	Gneissic hornblende-biotite quartz diorite
3	Jurassic(?) intrusive rocks: pre-tectonic; metamorphosed, mafic-rich diorite	
2	Upper Triassic(?) Cadwallader Group(?): metamorphosed volcanic and sedimentary rocks	
	2	Undifferentiated
	2a	Argillite
	2b	Quartzite; quartz-rich granofels and gneiss
	2c	Marble; calc-silicate skarn
	2d	Quartzofeldspathic granofels, gneiss, schist
	2e	Grey phyllite
	2f	Green phyllite
	2g	Sericitic phyllite
	2h	Biotite-plagioclase granofels
	2i	Greenstone; amphibolite
	2j	Mafic-rich gneiss, schist, augen gneiss
	2k	Meta-diorite (greenstone-related)
1	Paleozoic (or older) Gneiss Complexes (not exposed in area mapped)	

Meager Volcanic Complex (Woodsworth, 1977) but only the second youngest has been observed in the map area, where it forms a substantial part of bedrock geology. This unit (Unit 2) is the Cadwallader(?) Group of Read (1979) (Gambier Group of Woodsworth, 1977). It has been divided into 11 subunits on the basis of composition and texture.

Volcanic rocks (Unit 9) and related hypabyssal dykes have been divided on the basis of Read's (1979) stratigraphy, although it has not been possible to match every hypabyssal dyke seen to its extrusive equivalent.

2.2 Basement Lithology and Stratigraphy

2.2.1 Metamorphic Rocks (Unit 2)

The oldest unit (Unit 2) in the area mapped is a sequence of metamorphosed volcanic and sedimentary rocks which represent the Upper Triassic(?) Cadwallader Group(?) of Read (1979) (Cretaceous Gambier Group of Woodsworth, 1977). Recrystallization has destroyed the primary textures of most of these rocks. Nevertheless the nature of their precursors can be deduced, in most places, from their mineral composition (see Appendix A). Most of these rocks have been metamorphosed to middle or upper greenschist facies. Grade of metamorphism locally rises to amphibolite facies adjacent to large masses of quartz diorite (Unit 4).

The rocks of Unit 2 are heterogeneous and lack a well-defined stratigraphy. Contacts are commonly gradational and there are a few marker horizons. Those that have been identified are shown with exaggerated thickness on Figure 5. Noteworthy marker strata include rusty, sericitic phyllite (2g), laminated to thinly bedded argillite (2a) and marble (2c). Contacts between sequences of predominantly metasedimentary rocks (e.g. 2b, 2d) and metavolcanic rocks (e.g. 2i) also assist in correlating stratigraphic succession.

The stratigraphic succession in each of Job, Affliction, and Mosaic Creeks shows noteworthy similarities and contrasts (Figure 5).

In Job Creek, south of L2-80D and the contact with the Tertiary Fall Creek Stock, the stratigraphic sequence from north to south is: predominantly metasedimentary rocks (mixed pyritiferous quartzites (2b) and biotite-quartz granofels and gneiss (2d)) followed by massive greenstones

(2i) with associated synvolcanic diorite sills (2k) and grey granofels (2h) that may be either metasedimentary or metavolcanic. This is separated from a thick series of grey and green phyllites (2e,f) by a thin (less than 10m thick) but distinctive marker horizon of sericitic phyllite (2g) with minor quartzite (2b). This marker horizon is inferred to extend as far west as the east side of Affliction Creek. From the sericitic phyllite marker to near the terminus of Job Glacier is a sequence of intercalated grey and green phyllite (2e,f) with minor greenstone (2i), and argillite (2a). These phyllites probably represent metamorphosed tuffs, tuffaceous sediments, or interbedded tuffs and immature clastic sediments. Marble (2c), another marker horizon, is found near the terminus of Job Glacier as thin beds and pods. Some of these have been thermally metamorphosed to a calc-silicate skarn by numerous granitic sills of Unit 7. Mafic-rich gneiss and schist (2j) are more abundant closer to intrusive Units 3 (diorite) and 4 (quartz diorite). This may reflect an increase in metamorphic grade in rocks that are essentially the same composition as the grey and green phyllites (2e,f).

In Affliction Creek, the stratigraphic sequence from north to south is first, greenstone (2i; more properly termed an amphibolite due to the abundance of porphyroblasts of hornblende and actinolite), then mixed grey and green phyllite (2e,f) in the midst of which is a marker horizon of argillite (2a). This argillite is inferred to extend west into Mosaic Creek and may possibly be represented in Job Creek by isolated lenses such as found immediately north of L4-82D. South of the phyllitic unit there is a gradational increase of mafic-rich gneisses (2j) towards the contact with quartz diorite (4). A sizable enclave of mafic gneiss and schist (2j), with numerous sills of quartz diorite (4), underlies the area just south of the confluence of Affliction Creek and its main tributary (MTA Creek).

The deeply-incised middle reaches of Mosaic Creek have the best continuous exposures of Unit 2 although they are difficult of access. The section here is thinner and consists simply of greenstone (2i) in the north and phyllite (2e,f) in the south. There is an argillite (2a) marker horizon in the phyllite near the contact with the greenstone. The phyllite grades into mafic gneisses and schists (2j) towards the contact with quartz diorite (4).

A cliff-forming exposure of argillite (2a) located north of Mosaic Creek does not appear to continue southeast along strike much beyond its limit of outcrop.

2.2.2 Plutonic Rocks (Units 3,4,5,7 and 8)

The oldest plutonic unit identified is a strongly sheared and recrystallized mafic-rich diorite (Unit 3). It is mostly confined to the area immediately adjacent to the terminus of Job Glacier but also occurs as sills in Unit 2 and as inclusions in quartz diorite (Unit 4). The diorite is intimately mixed with mafic gneiss (2j) which occurs as numerous conformable inclusions.

Quartz diorite (4) forms the most extensive plutonic unit and is the same rock type that crops out extensively in the South Reservoir Area (NSBG, 1982). Three subdivisions of this unit have been identified on the basis of texture (e.g. degree of recrystallization and foliation). These subunits appear to be intergradational but may reflect separate intrusive episodes.

Quartz diorite (4) locally includes numerous xenoliths, especially of mafic gneiss (2j) and amphibolite (2i). Sills of quartz diorite can occur in metamorphic rocks up to several hundred metres from the main Cadwallader Group/quartz diorite contact. This contact, although clearly intrusive, is not sharply defined. In Mosaic Creek, where the contact is best exposed, foliated quartz diorite begins to carry increasing amounts of gneissic xenoliths grading to predominantly gneiss and phyllite with quartz diorite sills over about 150m (true stratigraphic thickness). Quartz diorite sills become fewer and thinner further from the contact zone.

Two kinds of unrelated dykes have been assigned to Unit 5. Both dykes were found cutting quartz diorite (4), for example, in MTA Creek valley, but not tonalite-diorite (Unit 7). Although they have dissimilar textures (5a is a diorite; 5b is an andesite) they have comparable alteration and degree of recrystallization so are probably of similar age.

Unit 7 comprises a distinctive pluton characterized by its intrusive style--that of numerous sills (or dykes that cut foliation at a low oblique angle) rarely more than a few metres thick. On the west side of Job Creek, near the terminus of Job Glacier, the pluton attains a thickness of about 150m. At its thickest point the sill has a hornblende-rich dioritic phase (7c) essentially restricted to that area. In general the pluton appears fresh and only weakly recrystallized and mostly consists of biotite-hornblende tonalite to quartz diorite. These sills are possibly the same age as the lower Cretaceous Spidery Peak Pluton exposed south of Meager Creek (Read, 1979).

The most widespread plutonic rocks other than quartz diorite (4) are exposed at the head of Affliction and Mosaic Creeks and around L2-80D (Unit 8). These are high-level, Miocene-age (circa 10 m.y.a.; Read, 1979) stocks consisting of either light grey biotite granite to granodiorite (Affliction Creek Stock, 8a) or light pink leucogranite (Fall Creek Stock, 8b). Contacts with other basement units are sharp, chilled, and locally disruptive. The plutons may be extensive at depth: L3-80D penetrated 750m into Fall Creek Stock with no indication that the drill hole terminated near country rock. Rocks similar to Affliction Creek Stock have been intersected in MC1 and MC3. These granites have thermal conductivity values about twice those usually obtained for metamorphic or quartz diorite units. This may have an important bearing on the interpretation of drill-hole temperature gradients.

2.3 Basement Structure

Based on reconnaissance mapping in 1981 (McCullough, 1982; NSBG, 1982) the major structures tentatively proposed for the North Reservoir area included faults in Job and Affliction Creek valleys and anticlinal folds. The faults were inferred to have a left-lateral sense of strike-slip displacement in order to align certain stratigraphic elements. Anticlines were proposed to explain divergent dips seen on the east side of Job Creek and in Affliction Creek. These proposed structures satisfactorily accounted for the data gathered to date.

New data, obtained in 1982, permit a reinterpretation of these proposed structures. The reinterpretation discussed below synthesizes information gained from all three major drainages in the map area.

2.3.1 Faults

Exposure is too poor to rule out the existence of major faults in Affliction or Job Creek valleys. However, detailed examination of the stratigraphy in these valleys indicates that there is sufficient continuity of both large heterogeneous units and key marker strata or contacts to suggest either that such faults do not exist or that movement on them is very small. In Job Creek the lack of apparent offset on either the Fall Creek Stock (8a) contact or tonalitic sill (7a) contact would set an upper limit on age of movement to Miocene or Cretaceous. In Job Creek valley, in particular, the use of metamorphic stratigraphy to estimate fault offsets is hampered by poor exposure, which requires extrapolation across 500m or more between valley walls, and by variations in attitudes due to local folding.

In Affliction Creek many of the lithologic variations noted by McCullough (1982) and used as supporting evidence for a fault hypothesis appear, on re-examination, to be due to the marked heterogeneity of the metamorphic rocks of Unit 2.

Numerous small faults and fault zones were observed in the map area. Many are sub-parallel foliation. Displacements, where seen, are less than a few metres although brecciation along faults can be intense. In L7-82D for example, drilling was retarded by several zones up to 5m thick that consisted of intensely fractured rock and clay-like gouge produced from comminution and possible alteration. These zones weather recessively in outcrop and so can be easily overlooked during mapping.

Areas of unusually intense fracturing have been identified on the map as "fracture zones". Although the zones mapped in Job and MTA Creeks have little alteration associated with them such structures would appear to be valuable as conduits for fluid movement. Based on surface evidence, such zones may have only short lateral extent at depth. The Upper Affliction Creek area, particularly MTA and L7 Creeks, is an area of anomalously intense faulting and fracturing. The area is also the site of large intrusive plugs and dykes of porphyritic andesite (9e/P6i). These joints and contacts favour high subsurface porosity, if these conditions extend to depth.

The distribution of fault and fracture zones cannot as yet be fitted into a unified structural model. Individual fracture sets could be preserved from any stage of the geological history recorded in the area when rocks were cool enough to sustain brittle failure. Fractures and faults have resulted from combinations of the following factors: regional or local folding of the Cadwallader Group; emplacement and cooling of the diorite, quartz diorite, tonalite, or granite plutons; recent volcanism with its subvolcanic magmatic activity; subduction-related regional tectonic forces; and, most recently, uplift and erosion.

2.3.2 Folds

An appreciation of folding in the metamorphic rocks of Unit 2 is necessary chiefly to determine whether or not the observed variation in stratigraphy is due to faulting. Fold information is also useful as a potential tool for orienting drill core and for identifying fold-related fractures that may contribute to regional porosity.

The variation in dips of strata from northerly to southerly in both Job and Affliction Creeks is one of the most perplexing structural features in the map area. Reconnaissance mapping to 1981 suggested this was due to an antiform whose axial surface was located slightly south of L4-81D. This hypothesis does not account for the consistent southerly dips of most rocks on the west side of Job Creek, nor the consistent northeasterly dips in Mosaic Creek, nor is it supported by any convincing repetition of strata that would be expected around such a structure.

A hypothesis that is consistent with observations in all three drainages is that the strata are part of the southern limb of a large, southeasterly-striking synform that is overturned and open to the northeast (Figures 3,4). Structural analysis of foliation attitudes (Figure 2) suggests such a structure would have a fold axis that plunges from 0° to 20° towards 120°. No information on the hinge zone for such a structure was discernible in the field. Local variation in attitudes of strata is attributable to minor parasitic folds on the limb, or possibly to superimposed folding around north-south striking axes. Post-tectonic intrusions (Units 7 or 8) could locally deflect strata from regionally consistent patterns.

Evidence of superimposed or polyphase deformation can be inferred on the basis of intensity of deformation, transposition of minor folds, and folding of boudins particularly in phyllitic units (e.g. 2e,f). At present this evidence is permissive but not conclusive.

2.4 Hydrothermal Alteration

Hydrothermal alteration in both basement and volcanic rocks is a distinctive but restricted feature in the map area. Six areas, representing the range of hydrothermal phenomena seen, will be discussed:

1) upper Job Glacier (altered volcanic rocks)
2) confluence of MTA and Affliction Creek valleys (alteration and fracture zones)
3) upper Mosaic and Affliction Creek Valleys (alteration in Affliction Creek Stock)
4) L7 Creek (altered, quartz diorite/andesite contact)
5) Twin Creeks (travertine)
6) Job Creek (H_2S vent)

2.4.1 Upper Job Glacier Area

Underlying the north flank of Job Mountain and a nunatak located about 1km to the north are altered Pleistocene volcanic rocks which record the effects of geologically recent, high-level, hydrothermal activity. Both areas are underlain by three compositionally similar rhyodacite units (9b; 9c; 9d; Read, 1979). Only the rocks of the nunatak were observed at close range.

The oldest unit on the nunatak is a distinctive, rusty-yellow, plagioclase-quartz-hornblende-biotite-porphyry rhyodacite (9d). It consists of thinly layered, locally welded, ash flows that are well jointed and moderately fissile. The unit has contorted layering (dipping steeply to the southeast and southwest, and vertically) and is extensively altered. Alteration primarily has converted the groundmass of the rock to clay (illite?). The alteration could be a product of leaching by acidic hydrothermal fluids such as would be associated with fumarolic activity. The prevalence of clay alteration makes the rock a strong conductor in resistivity surveys. The alteration has penetrated the rock primarily along parting planes parallel to bedding. Alteration is strongest immediately adjacent to parting planes, decreasing towards the cores of some of the thicker layers.

The irregular dips and folds in this unit lack axial planar joint sets and a coherent fold symmetry. Older andesites near the nunatak do not show tectonic displacement (Read, 1979). The folds in this unit are thus inferred to be due to deposition over a pre-existing, rugged terrain; that is, they are supratenuous and flow-related rather than tectonic. Alteration does not transgress the contact with younger rhyodacite (9c). It appears to have commenced perhaps shortly following the deposition of the rock, about 150,000 years ago (Read, 1979) and ceased before the onset of renewed volcanism of the Capricorn Assemblage.

The contact with overlying rhyodacite (9c) is an east-west striking, steep south-dipping angular unconformity. Alteration predates deposition of this unit. The younger rhyodacite is a grey and red, plagioclase-quartz-biotite porphyry. It is distinguished from 9d by colour, lack of alteration and welding, thicker layering, and blockier jointing. Dips vary from moderate northwest to steep southwest, almost certainly as a result of flow over uneven terrain, such as the eroded, chaotically-folded knob defined by Unit 9d.

The youngest unit on the nunatak consists of a non-welded, poorly layered, crystal tuff (plagioclase-biotite-quartz-porphyry rhyodacite; 9b) that unconformably overlies 9c and dips towards the northeast. This unit is also unaltered.

2.4.2 <u>Affliction-MTA Creek Area</u>

Propylitic, argillic, and pyritic alteration is a distinctive feature of the area around the confluence of MTA and Affliction Creeks. The most widespread effect is the appearance of pyrite (either disseminated or fracture-filling) and green clay, chlorite or actinolite (coating fractures). Argillic alteration is typically patchy and especially affects feldspar phenocrysts in some hypabyssal dykes. Zones of intense argillic alteration up to a few metres across occur in quartz diorite (Unit 4) and gneisses (Unit 2). Alteration is locally intense enough to obliterate original rock texture.

Some of these alteration zones are spatially related to minor faults and fracture zones. The alteration affects basement rocks and some hypabyssal dykes but not the most recent volcanic flows capping bedrock (Unit 9f) nor the latest pre-flow dykes. The coincidence of fracturing, faulting, and hydrothermal alteration demonstrate the importance of these structures to hydrothermal fluid circulation.

2.4.3 <u>Affliction Creek Stock</u>

Parts of the Affliction Creek Stock have undergone sericitic and argillic alteration particularly adjacent to fractures coated with calcite, quartz, pyrite, and locally, sphalerite. Occurrences are northwest of the terminus of Mosaic Glacier and in upper Affliction Creek valley. Near Mosaic Glacier the alteration zone is associated with numerous veins, miarolitic cavities, and an apparently autobrecciated phase of the pluton. Alteration here predates emplacement of a hypabyssal dyke, and may in fact be related to late (pneumatolytic) stages of the emplacement and cooling of the pluton. Elsewhere age of alteration is less well defined.

Comparable, but much less intense alteration is seen in drill core from L2-80D and L3-80D which penetrated the Fall Creek Stock (8a). In L3-80D, for example, chloritic and sericitic alteration is characteristically associated with zones of now-healed fracturing and ductile shearing.

2.4.4 L7 Creek

In L7 Creek, two hypabyssal plugs and several radiating dykes occur that consist of plagioclase-porphyry andesite (Unit 9e). Adjacent to the contacts of these intrusions, quartz diorite is soft, crumbly, and granular-weathering. The width of this alteration zone ranges up to several metres, depending on the size of the andesitic intrusion. The observed transformation is considered to be mainly a product of thermal metamorphism but some clay alteration is also present.

2.4.5 Twin Creeks

Several outcrops near the terminus of Job Glacier, particularly immediately north of Twin Creeks, are coated with travertine. Precipitation is not presently occurring but coating of glacio-fluvial gravels indicates very recent activity. The source of the carbonate may be from marble beds exposed in adjacent outcrops and mobilized by thermal groundwaters.

2.4.6 Job Creek H_2S

Job Creek valley is well known as a site of H_2S emission. The H_2S is apparently emitted from a vent located beneath Job Glacier and is released from meltwater runoff. Although no other vents have been positively identified, they are suggested by traces of H_2S noticed at a few places between the north flank of Plinth Peak and the west side of Affliction Creek. The presence of H_2S is a positive indication that there may be fumarolic hydrothermal activity relatively near surface under the north flanks of the mountains in the map area.

3.0 CONCLUSIONS

The following conclusions can be drawn from this mapping program.

1. The structure that best fits stratigraphic data from Mosaic, Affliction and Job Creeks is that of a gently south-east plunging synform that is open and overturned to the northeast. Such a structure may have a related fracture system that could provide a regional porosity to the area, particularly in more competent units.

2. Faults appear to be small and locallized although there can be intense brecciation along them.

3. Fractures are widespread in the study area, but fracture zones are localized. As yet there are insufficient data to integrate fracture orientations into a coherent regional pattern.

4. Affliction Creek drainage, especially around MTA and L7 Creeks is, at surface, an area of greater than average fracturing, faulting, alteration, and occurrence of major hypabyssal intrusions, all of which have a bearing on the geothermal potential of the area. Alteration has affected plutonic and hypabyssal rocks and may be currently active at depth. This is suggested by the high temperature gradient (88°C/km) in L7-82D, despite its high elevation, and the presence of a resistivity anomaly beneath the upper reaches of Job and Affliction Creeks. Fractures, faults, and intrusive contacts provide for enhanced porosity that would aid the movement of hydrothermal fluids.

4.0 RECOMMENDATIONS

1. In order to effectively plan a deep exploratory drilling program, we advise obtaining more information on fracture patterns, temperature gradients, distribution of lithologies, and thermal conductivities in the North Reservoir area.

2. Fracture Studies: More work needs to be done to try to integrate fault and fracture data into a unified regional model. It is recommended that a study of fractures be conducted taking into account the diversity of rock types and possible origins of fault and fracture sets. The study would include airphoto interpretation and field measurement of fracture orientations and would incorporate data already obtained from drill holes and the South Reservoir area. The

field data should be of value in predicting the fracture systems likely to occur in various reservoir rocks that will be encountered in deep drilling.

3. Slim Hole Drilling: In order to test the extent of the anomalous thermal gradient in L7-82D, zones of intense fracturing, faulting and alteration, and area of low resistivity, it is recommended that a shallow (500m) hole be drilled from a site near the confluence of MTA and Affliction Creeks, about halfway between Affliction Glacier and L8-82D. Additional temperature gradient drill holes might be considered on the ridge between Affliction and Mosaic Creeks and in upper and lower parts of Mosaic Creek valley in order to better define regional heat flow, resistivity patterns, and subsurface lithologic relationships.

4. Thermal Conductivity Studies: In the north reservoir area interpretation of temperature gradients in drill holes is especially difficult because of the diversity of rock types and their respective thermal conductivities. It is recommended that thermal conductivity measurements of a complete suite of rock and drill core samples be done in order to accurately evaluate heat flow in the study area.

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APPENDIX A DESCRIPTIONS OF BASEMENT ROCK UNITS

Brief petrographic descriptions of selected units are provided as an aid to recognizing them in drill core or cuttings and for identifying stable, pre-alteration mineral assemblages.

Unit 2 Triassic(?) Cadwallader Group

2a Argillite

Argillite forms a distinctive marker unit, useful for correlating the stratigraphy of the area. It is rusty weathering, black on fresh surfaces, aphanitic to fine grained, massive to thinly laminated, and commonly fairly fissile. It consists mostly of quartz, with graphite as the main dark mineral defining foliation. Feldspar is a minor constituent phase. Locally pyrite, sericite, chlorite and epidote are found as accessories. Apart from a major cliff-forming exposure located north of Mosaic Creek, argillite typically forms seams less than 10 to 20m thick.

2b Quartzite, quartz-rich granofels and gneiss

This unit comprises rocks distinguished by high quartz content despite rather variable colour and texture due to the presence of other minerals. Minor but variable amounts of clinozoisite, sericite, biotite, chlorite and pyrite give this unit its grey, pink or white colours. Rocks are fine to medium grained; textures vary from massive to poorly layered, locally well foliated or lineated. Quartz-rich rocks are closely associated with sericitic phyllite (2g) and some quartzofeldspathic rocks (2d).

2c Marble; calc-silicate skarn

Creamy white, medium to coarse crystalline marble, with seams of phyllite or schist, occurs especially near Twin Creeks in Job Creek valley. The marble has been locally replaced by epidote, grossular garnet, diopside, tremolite and forsterite along contacts with sills of Unit 7. In outcrop the unit exhibits ductile deformation. It occurs as lenses and thin sheets, up to a few metres thick, intercalated with mafic phyllite, schists, and gneisses.

2d Quartzofeldspathic granofels, gneiss, and schist

This is a heterogeneous unit distinguished by its predominantly quartzofeldspathic composition, although feldspars are commonly replaced by zoisite, clinozoisite, and epidote. Textures range from massive to foliated to thinly layered or gneissic or, locally, schistose. Colours range from light to dark grey, to black or greenish grey. Green colours are primarily due to epidote group minerals replacing feldspar. Biotite (with green pleochroism) is the principal mafic mineral, locally forming 30% of the rock. Pyrite, sericite, chlorite, hornblende, and garnet are local accessory phases.

2e Grey phyllite

Medium to dark grey or black, locally greenish, fine to medium grained, thinly layered or schistose, this unit is composed of fine granular quartz and feldspar with biotite, actinolite, and minor sericite defining fabric. Locally the rock has leucocratic quartz and feldspar-rich seams.

2f Green phyllite

Medium green with paler and darker green layers, this unit is composed of feldspar and quartz with actinolite as the major mafic mineral. Biotite and hornblende are subordinate mafics; chlorite, calcite, pyrite, magnetite and sphene are accessory phases. Clinozoisite replaces feldspar in some samples.

Note: Units 2e and 2f are closely associated, and intercalated, with each other. Outcrops typically show minor crenulations on foliation surfaces as well as boudinage, drag folds, and dismembered, pretectonic quartz veins as more prominent structural features.

2g Sericitic phyllite

This is a distinctive marker horizon. It is rusty weathering, silvery white to light grey and consists of essential quartz and sericite with minor feldspar and conspicuous pyrite. It is typically fine to medium grained, fissile, and crenulated. It forms less than 10m thick layers closely associated with quartz-rich or quartzofeldspathic rocks of Units 2b and 2d.

2h Biotite-plagioclase granofels

Light to medium grey, fine grained, generally massive but locally thinly layered, this unit is mainly exposed close to outcrops of greenstone. The rock consists of fine granular plagioclase with biotite, subordinate actinolite and accessory pyrite, calcite, scapolite, and chlorite. The texture of this rock suggests it may be a non-porphyritic metavolcanic.

2i Greenstone, amphibolite

Both greenstone and massive amphibolite are included in this unit because of comparable composition and stratigraphic location, and because they are both inferred to have been derived from a volcanic protolith. (Gneissic amphibolite is included in Unit 2j because it is spatially associated with other mafic-rich gneisses, even though it may also be metavolcanic). Greenstone is dark greyish green to dark green, (locally light grey where feldspar-rich) and generally fine grained. It is distinguished by the presence of relict phenocrysts of plagioclase in an otherwise fine granular groundmass, or by porphyroblasts of actinolite and/or hornblende. The groundmass consists of plagioclase, actinolite, minor hornblende, and biotite with accessory pyrite. Massive amphibolite mainly occurs in the lower reaches of Affliction Creek, near L8-82D, where the rocks contain abundant hornblende porphyroblasts and thin sprays of actinolite.

2j Mafic-rich gneiss, schist, and augen gneiss

This unit comprises various mesocratic gneissic rocks that typically are found in the vicinity of the contacts of dioritic and quartz dioritic plutons of Units 3 and 4. The unit consists of fairly well layered, medium grained gneiss, minor schist, and streaky, augen-textured gneiss which have more than 15 to 20% mafic minerals. Dark layer are rich in hornblende and/or biotite, with minor actinolite and secondary chlorite. Light layers consist of quartz and feldspar (locally replaced by epidote or clinozoisite). Sericite, apatite, pyrite, magnetite, sphene and calcite are accessory phases.

2k Greenstone-related meta-diorite

This uncommon rock occurs as a thin conformable zone associated with greenstone north of L4-81D. It consists of a light grey, fine grained feldspathic groundmass with acicular poikiloblasts of hornblende up to 5mm long. The groundmass has magnetite as its principal accessory. The rock could be either a thermally metamorphosed granofels (Unit 2h) or a synvolcanic diorite sill.

3 Mafic-rich diorite

This unit is exposed mainly near the terminus of Job Glacier. In outcrop it is dark grey to black weathering and crisscrossed by many ductile shear zones and quartz veinlets. The diorite has numerous conformable inclusions of mafic gneiss of Unit 2j. In thin section it consists of plagioclase, hornblende, biotite, minor quartz and accessory pyrite, magnetite, chlorite and calcite. The rock is weakly to moderately recrystallized, and little altered.

4 Quartz Diorite

Although divided into three subunits on the basis of texture this unit shows very little compositional variation. It consists of plagioclase, quartz, hornblende and biotite with minor or accessory epidote, magnetite, chlorite, apatite, and sphene. In altered varieties clay or sericite and calcite replace plagioclase; chlorite replaces mafic minerals; and pyrite has been introduced. Some fractures are filled with actinolite, calcite, and/or epidote.

The freshest samples of quartz diorite exhibit minor strain features such as bent biotite or plagioclase grains. With increasing foliation, quartz and plagioclase are more recrystallized along grain margins, and hornblende is partially replaced with biotite and chlorite.

7 Granitic sills

This unit is distinguished in outcrop from fresh varieties of Unit 4 by its sill-like intrusive style and fresher (less altered and recrystallized) appearance. In thin section this unit consists of well zoned, subhedral plagioclase, weakly strained quartz, and variable amounts of biotite and hornblende with generally very weak alteration. Dioritic phases may well be products of cumulate processes since they are unusually rich in hornblende. Most varieties of Unit 7 have more quartz than comparable rocks of Unit 4.

8a Affliction Creek Stock

This pluton consists of light grey to pinkish grey, equigranular to subporphyritic granodiorite and granite. In thin section plagioclase (40-50%) forms subhedral, zoned grains; K-feldspar (20-40%) is perthitic and anhedral, and quartz (15-25%) forms irregular anhedral grains with smoothly curved grain margins. Biotite, the main mafic mineral, forms up to 10% of the rock. Pyrite is the main accessory.

8b Fall Creek Stock

This pluton mainly consists of light pink, medium to coarse grained leucogranite with subequal plagioclase and perthitic K-feldspar and about 20% quartz. Biotite (less than 5%) is the principal mafic mineral.

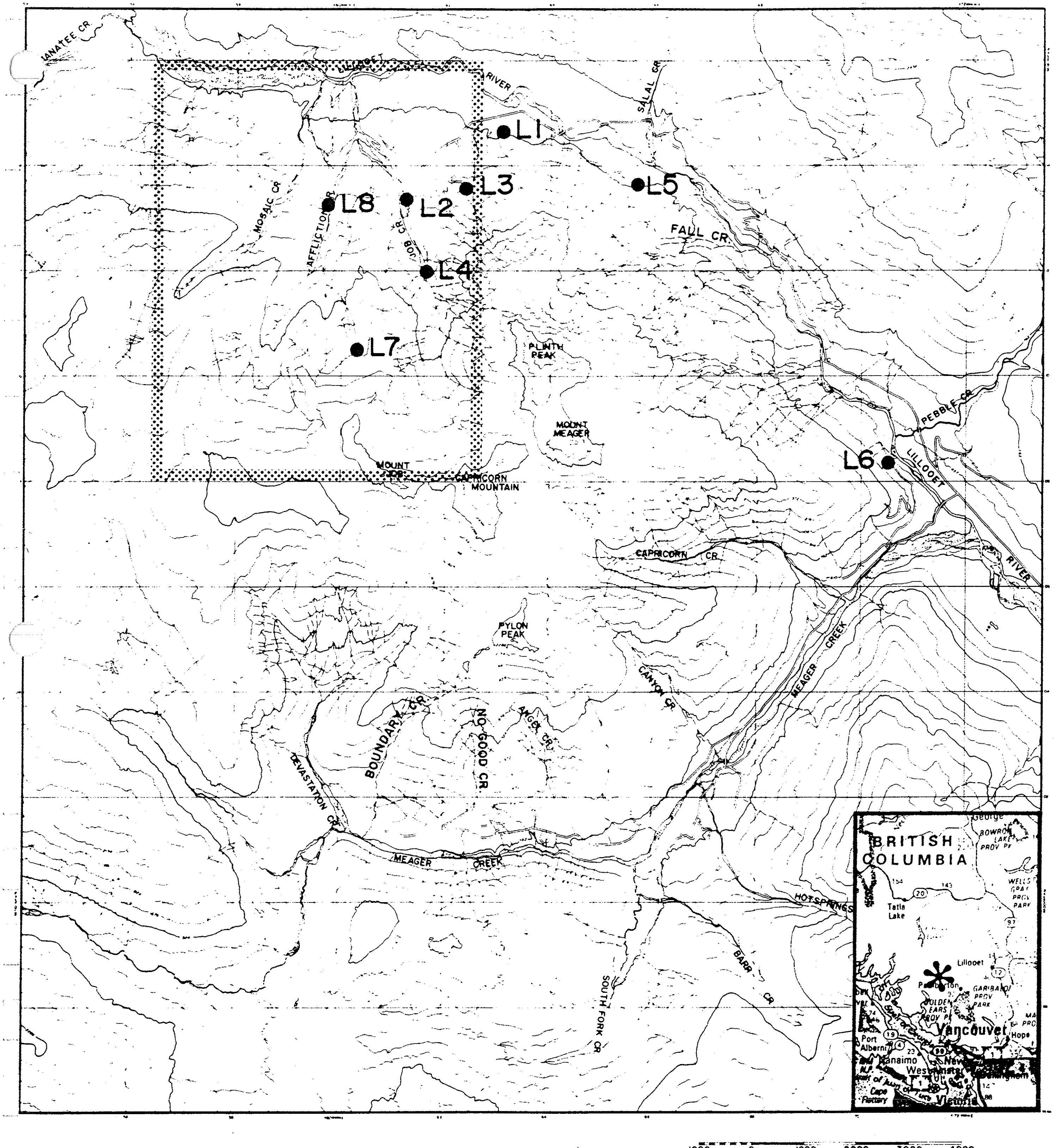


FIGURE 1

LOCATION MAP

1% Contour Interval

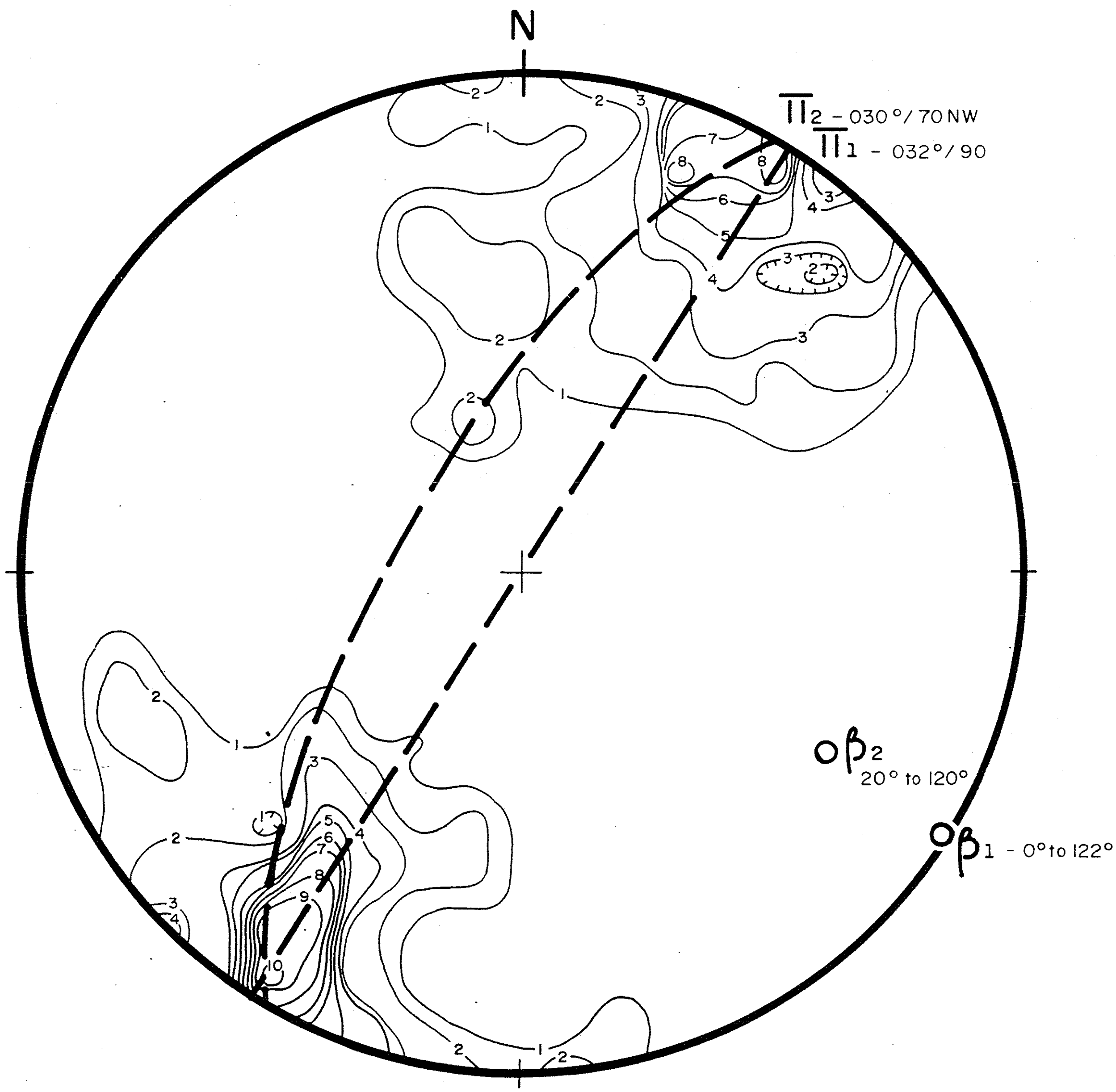
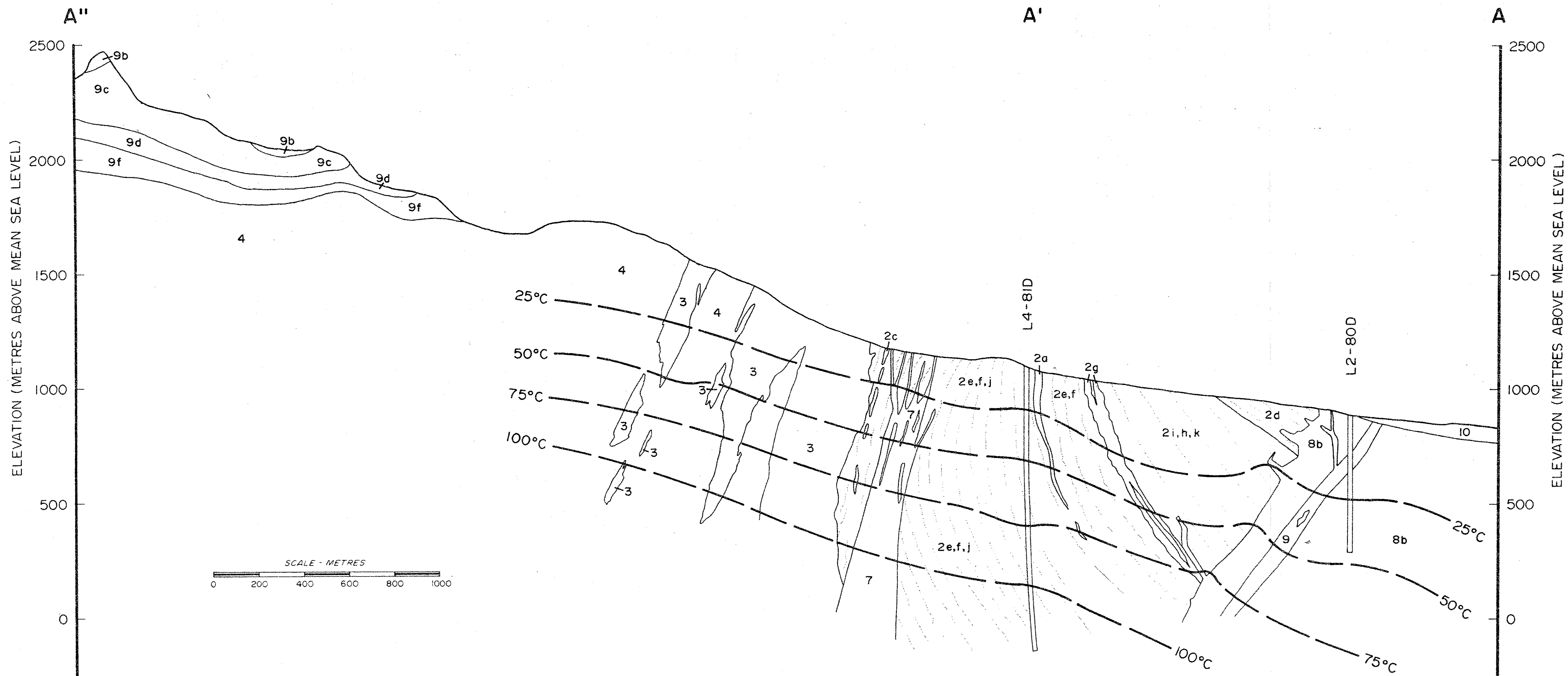


FIGURE 2

EQUAL AREA STEREO NET PLOT OF POLES TO FOLIATION (N=138)



LEGEND

(Condensed from Figure 5)

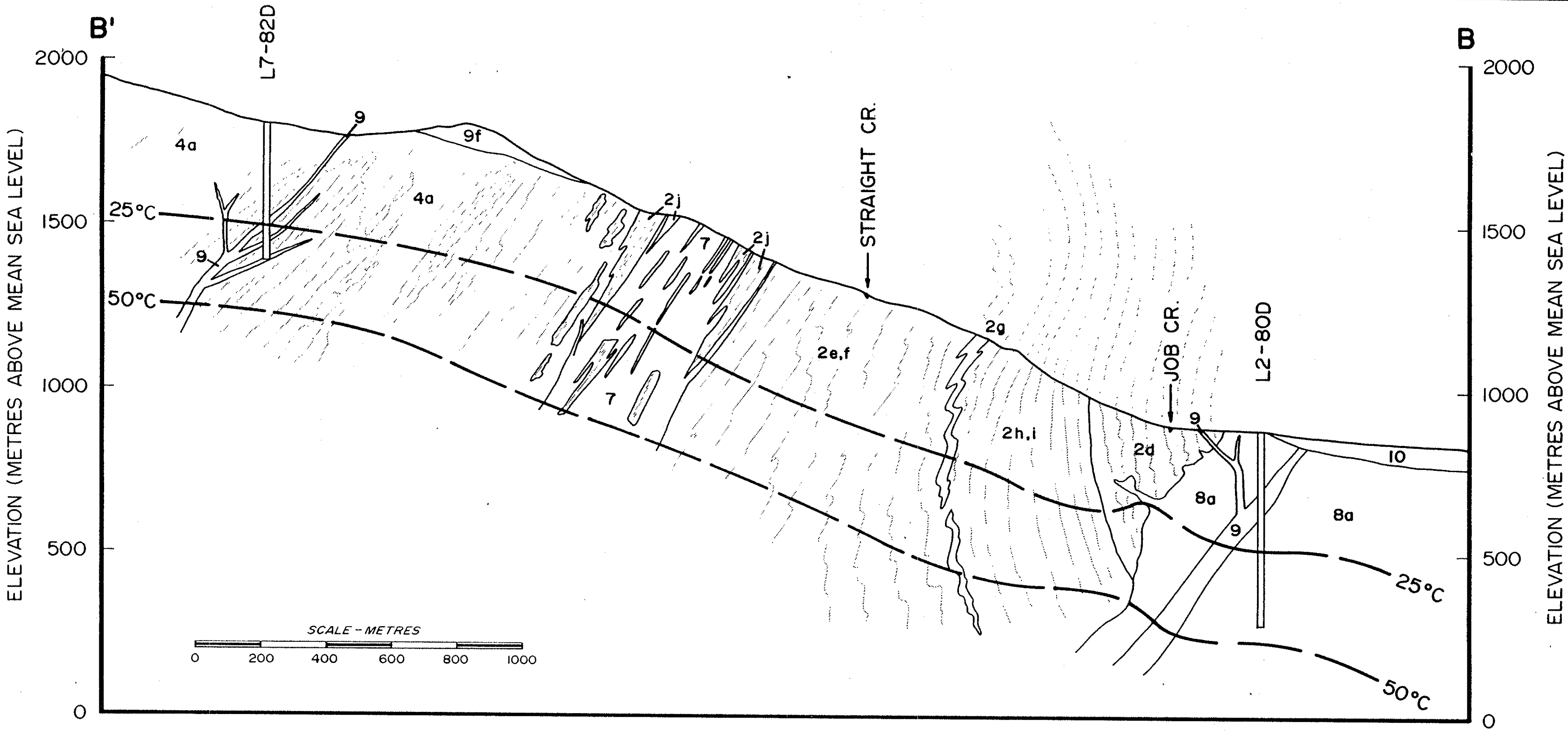
10 ALLUVIUM
9 MEAGER VOLCANIC COMPLEX
8 MIOCENE INTRUSIVES
7 CRETACEOUS (?) SILLS
4 JURASSIC (?) QUARTZ DIORITE
3 JURASSIC (?) DIORITE
2 TRIASSIC (?) CADWALLADER GROUP
- Argillite (2a)
- Quartzite (2b)
- Marble (2c)
- Sericitic phyllite (2g)
- Metasediments (2d)
- Metavolcanics (2h,i,k)
- Phyllite, Schist, Gneiss (2e,f,j)

25°C — ISOTHERMS

FORM LINES

FIGURE 3

MEAGER CREEK
NORTH RESERVOIR AREA
CROSS-SECTION A-A'-A''



LEGEND: (Condensed from Figure 5)

- 10 ALLUVIUM
- 9 MEAGER VOLCANIC COMPLEX
- 8 MIOCENE INTRUSIVES
- 7 CRETACEOUS (?) SILLS
- 4 JURASSIC (?) QUARTZ DIORITE
- 2 TRIASSIC (?) CADWALLADER GROUP
  - Sericitic phyllite (2g)
  - Metasediments (2d)
  - Metavolcanics (2h,i,k)
  - Phyllite, Schist, Gneiss (2e,f,j)

25°C ISOTHERMS

FORM LINES

FIGURE 4

MEAGER CREEK NORTH RESERVOIR AREA CROSS-SECTION B-B'